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The coronal fricative problem

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Abstract

This paper examines a range of predicted versus attested error patterns involving coronal fricatives (e.g. [s, z, θ, ð]) as targets and repairs in the early sound systems of monolingual English-acquiring children. Typological results are reported from a cross-sectional study of 234 children with phonological delays (ages 3 years; 0 months to 7;9). Our analyses revealed different instantiations of a putative developmental conspiracy within and across children. Supplemental longitudinal evidence is also presented that replicates the cross-sectional results, offering further insight into the life-cycle of the conspiracy. Several of the observed typological anomalies are argued to follow from a modified version of Optimality Theory with Candidate Chains (McCarthy, 2007).

Keywords

Typology; Error patterns; Optimality Theory; Conspiracy; Chain shift; Transparency; Opacity

1. Introduction

Coronal fricatives (e.g. [s, z, θ, ð]) have long been known to pose problems for young children acquiring English (e.g. Sander, 1972; Smit, 1986, 1993; Templin, 1957). These sounds are subject to a variety of error patterns within and across children, whether typically developing or delayed (e.g. Bernhardt and Stemberger, 1998; Dinnsen, Green, Gierut and Morrisette, 2011). Some of the common substitution processes known to affect coronal fricatives include, among others, Stopping (e.g. ‘sun’ [tʌn], ‘thumb’ [tʌm]), Labialization of interdentals (e.g. ‘thumb’ [fʌm]), and Dentalization of grooved fricatives (e.g. ‘sun’ [θʌn]).

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While some children employ just one strategy for dealing with these fricatives, others adopt a combination of processes, thereby effecting multiple repairs for different subsets of coronal fricatives. For example, one such combination involves the co-occurrence of Stopping of grooved fricatives (e.g. ‘sun’ [tʌn]) and Labialization of interdentals (e.g. ‘thumb’ [fʌm]). As we will see, these and other processes can also co-occur and interact in yet other ways within and across children’s phonologies. The different repairs embodied in these processes with their relative homogeneity of target, namely coronal fricatives, suggest that a ‘conspiracy’ may well be at the heart of the problem (e.g. Kiparsky, 1976; Kisseberth, 1970; Prince & Smolensky, 1993/2004).

Despite the ubiquity of this problem in young children’s developing phonologies, surprisingly little attention has been given to a systematic evaluation of the error patterns associated with coronal fricatives and even less to a unified characterization of the problem. There is, however, one recent study by Dinnsen, Green, Gierut and Morrisette (2011) that begins to address this issue with results from a cross-sectional investigation of 160 English-acquiring children with phonological delays (ages 3 years; 0 months to 7;9). These children were found to be typically developing in all other respects on the basis of extensive testing (see Gierut (2008b) for details). In terms of results, that study served to further substantiate the independent occurrence and interaction of the above cited error patterns affecting coronal fricatives (i.e. Dentalization, Labialization, and Stopping). An important additional finding of that study was the documented combination of Labialization and Dentalization, resulting in a counterfeeding interaction, such that target interdentals were realized as labial fricatives due to Labialization (e.g. ‘thumb’ [fʌm]), while grooved coronal fricatives were realized as interdentals due to Dentalization (e.g. ‘sun’ [θʌn]). Importantly, the interdentals derived from Dentalization did not undergo Labialization. This particular interaction of error patterns has also been amply documented elsewhere in individual case studies of young children’s developing phonologies, normal and disordered (e.g. Bernhardt & Stemberger, 1998; Dinnsen & Barlow, 1998; Ingram, 1989; Jesney, 2005; Smith, 1973; Velleman, 1988). While the Dinnsen, Green, Gierut and Morrisette (2011) finding regarding this interaction was not unexpected, it remains interesting for the empirical and theoretical controversies that it engenders (e.g. Dinnsen, O’Connor & Gierut, 2001; Ettlinger, 2009; Fikkert, 2006; Rose, 2006). The added interest of this interaction for the current paper is its connection to a putative conspiracy.

In addition to the observed counterfeeding interaction, there was one especially anomalous result that came out of the Dinnsen, Green, Gierut and Morrisette (2011) study. Specifically, none of the 160 children combined Dentalization and Labialization to yield what might be described as a feeding interaction between these two processes, such that all coronal fricatives would have been replaced by a labial fricative (e.g. ‘thumb’ *[fʌm] and ‘sun’ > *[θʌn] > *[fʌn]). The distinguishing property of a feeding interaction in this instance is that interdental fricatives, whether underlying or derived from Dentalization, should map to a labial fricative due to Labialization. The non-occurrence of this mapping was surprising because feeding interactions are usually associated with transparent (surface-true) generalizations and are presumed to represent unmarked states (e.g. Baković, 2011; Kiparsky, 1965, 1971). The absence of this feeding interaction is even more surprising from the point of view of a conspiracy because conspiracies are understood to yield transparent outputs (e.g. Kiparsky, 1976).

While these results begin to elucidate some of the typological characteristics of the coronal fricative problem, they also raise several questions regarding the role that a conspiracy might play. For one, how does the well-known, but controversial, counterfeeding interaction between Labialization and Dentalization fit in a larger developmental progression relative to the other attested error patterns affecting coronal fricatives? Additionally, what might explain the absence of a feeding interaction for these error patterns? Along similar lines, do other processes interact with one another with similar typological restrictions? These questions could not be addressed in the Dinnsen, Green, Gierut and Morrisette (2011) study, largely because of its more limited focus. That study was cross-sectional in nature and focused exclusively on children whose phonetic inventories included a labial fricative. The rationale for that restriction related to the study's attempt to establish the facts regarding the occurrence of logically possible interactions between Labialization and Dentalization, all of which involve /f/ as a potential product of these error patterns. That restriction raises the further issue of whether a broader focus might have revealed other error patterns and potential interactions with comparable anomalies. We are, thus, interested in knowing how the coronal fricative problem is impacted when a labial fricative is excluded from a child's phonetic inventory, i.e. when it is not available as a potential repair for a coronal fricative.

This paper attempts to get at these questions by expanding the empirical base of the Dinnsen, Green, Gierut and Morrisette (2011) study to include an additional 74 children with more impoverished fricative inventories. The focus is, thus, broadened to include consideration of the occurrence and interaction of two additional error patterns found in the phonologies of children who exclude labial fricatives from their inventories. One of these error patterns is the opposite of Labialization, replacing a labial fricative with an interdental fricative (e.g. 'fun' [θʌn]). We dub this error pattern 'Coronalization'. The other error pattern targets interdental fricatives and replaces them with a grooved fricative (e.g. 'thumb' [sʌm]). This error pattern is essentially the opposite of Dentalization and can be referred to as 'Grooving'. The processes of Coronalization and Grooving are also of interest because they have the potential to interact with one another in a feeding relation and a counterfeeding relation (much as Dentalization and Labialization did). The issue is whether they do, in fact, interact in these ways. The intent of the current paper will be to document the typological occurrence and interaction of these error patterns with one another and with Labialization, Dentalization and/or Stopping and to integrate these new findings with those from the earlier Dinnsen, Green, Gierut and Morrisette (2011) study. A longitudinal perspective will also be added to situate some of these error patterns in a developmental progression. The combined results from these two studies will be argued to reveal a novel conspiracy that points to new grammatical defaults and the need for additional theoretical restrictions to bring the theory into conformity with the attested typological facts. The analyses will be cast in optimality theoretic terms (e.g. Prince & Smolensky, 1993/2004), largely for the framework's advantages in characterizing conspiracies. To deal with some of the anomalous findings, the analyses will ultimately be amended to take advantage of certain insights of Optimality Theory with Candidate Chains (McCarthy, 2007).

The paper is organized as follows: In §2, the participants and methods are described. §3 reports the typological findings from the larger combined cross-sectional studies. That section begins with a classic optimality theoretic account of the children's inventories and the basic substitution processes affecting target fricatives. Other more challenging cases are then considered and are shown to require additional machinery not available in classic Optimality Theory, drawing specifically from the framework of Optimality Theory with Candidate Chains (henceforth OT-CC), as put forward by McCarthy (2007). Insight into the life-cycle of the putative coronal fricative conspiracy is offered in §4 by considering a child's longitudinal trajectory of phonological change over time. The discussion in §5 considers an apparent counterexample and some implications of our various proposals. The paper closes with a brief summary in §6.

2. Participants and methods of the expanded cross-sectional study

The current study examined the pretreatment phonologies of all 234 monolingual English-learning children from the same archive that was consulted in the Dinnsen, Green, Gierut, and Morrisette (2011) study. On the basis of extensive testing (see Gierut (2008b) for details), these children were found to be typically developing in all respects, except for evidence of a phonological delay. The focus is, thus, being expanded beyond the initial subset of 160 children who included a labial fricative in their phonemic inventories. The same analysis procedures were employed in this and the earlier study. All claims about the children's phonologies were based on comprehensive, pre-treatment speech samples and standard phonological analysis procedures (Gierut, 2008b). The speech sample for each child was elicited in a spontaneous picture-naming task and was audio recorded. The pictures related to a probe list of 544 words that were familiar to children of that age and that sampled the full range of English consonants in initial, medial, and final positions in multiple exemplars. The audio-recorded sessions were phonetically transcribed on the basis of impressionistic judgments by trained listeners who had considerable experience in the transcription of clinical populations. For transcription reliability purposes, 10% of all probes were retranscribed by an independent judge. The overall transcription reliability measure was 92% agreement for all phonologies, which is within the range of what is typically deemed acceptable (e.g. Shriberg and Lof, 1991). For the purposes of our analysis, the larger probe list of 544 words made available a minimum of 15–17 words that sampled each of the target fricatives, for a combined total of no less than 49 words per child. The palato-alveolar fricatives /ʃ/ and /ʒ/ were not included in this count, nor did they enter into our analyses due primarily to the voiced cognate's distributional asymmetries and its low token frequency of occurrence relative to other coronal fricatives in English.[1]

The pretreatment phonological records of all 234 children in the Archive were examined to establish each child's fricative inventory and the processes affecting those fricatives. For any fricative phoneme to be judged as occurring in the inventory, it had to occur with an accuracy at or above 20% and/or in at least two minimal pairs. Those target fricatives that did not meet this minimal criterion were classified as non-occurring and were especially

[1]The palato-alveolar fricatives were also excluded from consideration because of the potential complication introduced by the subsidiary place distinction between anterior and nonanterior coronal fricatives.

relevant to the identification of a child's repair processes. This should not be taken to mean that substitution processes were limited to an account of the repairs for non-occurring target sounds. Rather, a sound might be produced correctly in some words (i.e. as few as 20% of the relevant tokens) with that same target sound being produced in error in certain other words. A substitution process that accounts for an error can, thus, be considered active, even if it does not affect all relevant words in the same way. To identify when a substitution process might be considered active, we adopted the operational definition that active processes were those that affected a minimum of 25% of relevant words with a specific repair (e.g. Dinnsen, Green, Gierut and Morrisette, 2011; McReynolds & Elbert, 1981). One reason for accepting a value as low as 25% is that it would be generous in identifying an interaction among processes, if one were to occur. This is important because even this seemingly generous criterion failed to identify certain predicted interactions. There is also some value in not accepting a lower criterion level because so few words would be affected (i.e. 4 or fewer words), making it difficult to differentiate random errors from those that are systematic. To further clarify the implementation of these criteria, consider the case of a child who might or might not have produced /s/ correctly in some words: If target /s/ were produced as [θ] in 25% or more of the relevant words, Dentalization was considered active. However, other substitutes for target /s/ that fell below the 25% criterion, such as a stop, [h], or a [s̪] (i.e. a distortion of the target phoneme), were not counted as evidence of Dentalization or any other active process.[2] The same strict criterion was applied to the identification of other processes.

The identification of an interaction between two processes requires that both processes be judged as active by the 25% criterion with one of two characteristic phonetic outcomes expected. Table 1 provides sample phonetic outcomes that would in principle be expected from the active participation of Dentalization and Labialization in a counterfeeding interaction or a feeding interaction. Table 2 illustrates the predicted outcomes for the same types of interactions when Coronalization and Grooving are judged to be active.

Certain inferences are necessary regarding the activity of a process in a feeding interaction. More specifically, in a derivational rule-based framework, the output of one process could immediately serve as the input to the other process, resulting in an output that wipes out any evidence of the intermediate derivational step. Consequently, it was assumed that processes such as Dentalization and Labialization were both active if at least 25% of the target /s/ words were realized with [f] as the substitute. Similarly, the processes of Coronalization and Grooving were both judged to be active in a feeding interaction if 25% or more of target /f/-words were realized with [s] as the repair. While this assumption might seem overly generous, we will show that it did not skew the results in favor of feeding interactions when there were none. No special inferences about the activity of these processes would be required in standard optimality theoretic accounts because the evaluation of output candidates is conducted in parallel.

[2]The particular distinction between [θ] and [s̪] was based on an impressionistic judgment by trained transcribers; acoustic analyses would not have been possible, especially given the limited number of tokens. Any resultant misclassification of these sounds would only impact our calculation of the number of cases exhibiting Dentalization, but it would not impact the larger typology (cf. Velleman, 1988).

3. Results

The first set of results (§3.1) describes the various restrictions on the children's fricative inventories alongside the attested repairs that are most clearly associated with the putative coronal fricative conspiracy. Those accounts are cast in terms of Classic Optimality Theory (e.g. Prince & Smolensky 1993/2004), largely for the framework's advantages in characterizing conspiracies. The second set of results (§3.2) describes other related repairs and anomalies that are theoretically more challenging and that benefit from a version of Optimality Theory with Candidate Chains (e.g. McCarthy 2007).

3.1 Inventories and basic processes

To get a handle on the general problem posed by fricatives, we begin by establishing the facts regarding the simple occurrence/non-occurrence of different classes of fricatives in the phonemic inventories of the 234 children in our study. We are especially interested in the non-occurrence of certain target fricatives because those gaps are an obvious source of evidence for children's repairs or processes, e.g. Dentalization, Labialization, Stopping, etc. Table 3 reports the number of children who, according to the criteria set forth above, exhibited labial fricatives, interdental coronal fricatives, and/or grooved coronal fricatives. The most impoverished inventories, namely those with no fricatives, are cited at the top of the table and were associated with 41 of the 234 children. The next three rows of the table specify the number of children whose inventories were limited to one of the three classes of fricatives (N = 48). Moving further down the table, the next three rows report the number of children whose inventories were limited to two fricative classes (N = 139). Finally, the bottom row reveals that 6 of the 234 children's inventories included all three classes of fricatives. It should be clear from these results that all of the logically possible fricative inventories were attested, and the vast majority of the children had a problem with one or more of these classes of fricatives.[3]

The optimality theoretic constraints that are relevant to an account of the inventories and the basic processes affecting fricatives are spelled out in (1). Adopting for the moment Classic Optimality Theory (e.g. Prince and Smolensky, 1993/2004), the preliminary constraint rankings for the basic processes of Stopping, Labialization, Dentalization, and Grooving are summarized as in (2). We also adopt throughout the widely held assumption that children's underlying input representations are target-appropriate (e.g. Smolensky, 1996b) and that faithfulness constraints are ranked as low as possible in the hierarchy (e.g. Hayes, 2004; Prince and Tesar, 2004). Our assumption about children's underlying representations is primarily based on the principle of Richness of the Base, which prohibits language-specific (and child-specific) restrictions on input representations (e.g. Smolensky, 1996a). This does not necessarily mean that children have target-appropriate underlying representations for all forms—but rather that we, as analysts, must provide for the possibility that they could have internalized richly specified representations. This shifts the descriptive responsibility to the

[3]For additional details about the prevalence of many of the associated error patterns and their interactions, see specifically Dinnsen, Green, Gierut and Morrisette (2011) and more generally Smit (1993). Importantly, insofar as this is a typological investigation, we will be focusing on the typological facts, rather than the number of children exhibiting a particular phenomenon.

constraint hierarchy to yield the observed outputs, no matter what is assumed about the input representations.

(1) Constraints

a. Markedness

*f: labial fricatives are banned

*θ: interdental fricatives are banned

*s: grooved coronal fricatives are banned

b. Faithfulness

ID[continuant]: corresponding input and output segments must have the same specification for the feature [continuant]

ID[place]: corresponding input and output segments must have the same primary place feature

ID[grooved]: corresponding input and output segments must have the same specification for the feature [grooved]

Our use of the feature [grooved] warrants some comment. We employ throughout the feature [grooved] to distinguish among fricatives, as opposed to using the similar, but more controversial, SPE feature [strident] (Chomsky and Halle, 1968). More specifically, the sibilant /s/ can be differentiated from the non-sibilant fricatives /f/ and /θ/ by the feature [+grooved]. This allows the non-sibilant fricatives to be grouped together under the feature [-grooved], capturing their acoustic similarities in terms of their low intensity and flat spectrum (e.g. Ladefoged and Maddieson, 1996; O'Connor, 1973; Silbert and de Jong, 2008; Velleman, 1988). This grouping also provides for the observed perceptual confusion that sometimes occurs for place of articulation among the non-sibilants (e.g. Velleman, 1988). Also, by specifying /f/ and /θ/ as [-grooved], the substitution of either one by the other (i.e. Labialization or Coronalization) can be expressed as a minimal change in place. The alternative SPE feature makes the empirically unsupported prediction that /f/ and /s/ share the feature [+strident] and should, thus, pattern together.

The constraints in (1) and associated hierarchies reflect well established typological properties of fully developed and developing phonologies. More specifically, fricatives are clearly marked relative to stops,[4] but there does not appear to be a markedness relationship among subclasses of fricatives. That is, in both cross-linguistic studies of fully developed languages and cross-sectional studies of children acquiring English, labial fricatives, interdental fricatives, and/or grooved coronal fricatives can each occur, or not, independent of one another (e.g. Gierut, 1998; Maddieson, 1984). This point is further supported by the case studies reported in this paper (N.B. Table 3). The process of Stopping (2a), thus, implicates a family of markedness constraints (i.e. *f, *θ, *s), any one of which bans a particular class of fricatives by dominating the antagonistic faithfulness constraint

[4]The prohibition against all fricatives in a child's phonology can be achieved by the undominated ranking of a family of individual markedness constraints such as *f, *θ, and *s. There is, thus, no need for a more general cover constraint such as *Fricative, except possibly as an informal abbreviation for the entire family of these markedness constraints.

ID[continuant], which would otherwise preserve the input manner feature [continuant] in corresponding output segments. A generalized place faithfulness constraint ID[place] preserves input place in the corresponding output. The exclusion of coronal fricatives and their replacement by stops is achieved by ranking *s and *θ over ID[continuant] and ID[place]. Target-appropriate realizations of labial fricatives follow from the ranking of ID[continuant] over *f (2b).

Another basic process, Labialization, affects the coronal place of interdentals, changing them to labial fricatives. By ranking *θ and ID[continuant] over ID[place], a labial fricative will be preferred over a coronal stop (2c). The process of Dentalization, which changes /s/ to [θ], preserves place, but involves a change from a grooved coronal fricative to a non-grooved fricative. Such a change requires, at the very least, that *s, ID[continuant], and ID[place] be ranked above ID[grooved], favoring an interdental fricative over a coronal stop or a labial fricative (2d). Finally, interdental fricatives are sometimes replaced by grooved coronal fricatives due to a process of Grooving. The hierarchy in (2d) would achieve this effect if the ranking of *s and *θ were simply reversed, as in (2e).

(2) Summary of preliminary constraint rankings for basic processes

- **a.** Stopping of all fricatives

  *f, *θ, *s ≫ ID[continuant], ID[place]

- **b.** Stopping of coronal fricatives (and target-appropriate realizations of labial fricatives)

  *θ, *s ≫ ID[place] ≫ ID[continuant] ≫ *f ≫ ID[grooved]

- **c.** Labialization of interdentals (and target-appropriate realization of other fricatives)

  *θ ≫ ID[grooved], ID[continuant] ≫ *f, *s ≫ ID[place]

- **d.** Dentalization of grooved fricatives (and target-appropriate realization of other fricatives)

  *s ≫ ID[continuant], ID[place] ≫ *θ, *f ≫ ID[grooved]

- **e.** Grooving of interdental fricatives (and target-appropriate realization of other fricatives)

  *θ ≫ ID[continuant], ID[place] ≫ *f, *s ≫ ID[grooved]

We will be expanding the list of repairs associated with these and other fricatives and elaborating our account, but it should be noted that the above cross-sectional typology and the different rankings of the same constraints across children result in different outputs, all of which are transparent. This is suggestive of a developmental conspiracy to avoid coronal fricatives. Note that none of the above scenarios resulted in multiple repairs for a given child. Different children dealt with coronal fricatives in different ways, which may or may not have required crucial rankings among the faithfulness constraints. Conspiracies in fully developed languages exhibit the same characteristics. Not all instances of a conspiracy must result in multiple repairs, nor must all conspiracies entail crucially ranked faithfulness constraints. Aside from the cross-sectional variants of a conspiracy, probably the most compelling evidence for a conspiracy within any given child's phonology would involve a crucial ranking among the faithfulness constraints, leading to different repairs for the same set of targets. An argument can be made that the above repairs are part of the same conspiracy by considering those children who dealt with coronal fricatives by employing one repair under some circumstances and a different repair under others. The data in (3), from Child 20 (age 4;7), are representative of such a case. This child excluded coronal fricatives from her inventory, replacing them with a coronal stop in the case of grooved coronal fricatives (3a) and with a labial fricative in the case of target interdentals (3b).

(3) Child 20 (age 4 years; 7 months)

a. Grooved coronal fricatives replaced by stops (Stopping)

[tʌ n] 'sun'	[maʊt] 'mouse'
[tɔk] 'sock'	[dwɔt] 'dress'

b. Interdentals replaced by labial fricatives (Labialization)

[fʊti] 'thirsty'	[fʌnʊ] 'thunder'
[tif] 'teeth'	[maʊf] 'mouth'

c. Labial fricatives realized target-appropriately

[wʊf] 'roof'	[naɪf] 'knife'
[goʊfi] 'goofy'	[fagjoʊ] 'fire'

Consistent with standard conceptions of a conspiracy, these processes resulted in perfectly transparent outputs. To achieve these different repairs within Optimality Theory, the constraints must be ranked as in (4). Note also that the constraint hierarchy corresponds with a standard schema for a conspiracy, i.e. one or more markedness constraints dominating two or more crucially ranked faithfulness constraints (e.g. McCarthy 2002a, 2008).

(4) Ranking for Stopping and Labialization

*s, *θ ≫ ID[grooved] ≫ ID[continuant] ≫ *f ≫ ID[place]

The tableaux in (5) and (6) for 'sun' and 'thirsty', respectively, support the ranking in (4).

(5) Stopping of grooved coronal fricatives

/sʌn/ 'sun'		***s**	***θ**	**ID[grooved]**	**ID[cont]**	***f**	**ID[place]**
a.	sʌn	*!					

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/sʌn/ 'sun'		*s	*θ	ID[grooved]	ID[cont]	*f	ID[place]
b.	θʌn		*!	*			
c.	fʌn			*!		*	*
d. ☞	tʌn				*		

In the case of an input grooved coronal fricative (i.e. /s/), the fully faithful candidate (5a) and the unfaithful fricative candidate (5b) are eliminated due to their violations of the undominated markedness constraints banning coronal fricatives *s and *θ, respectively. Because the remaining fricative candidate (5c) differs from the input by being [-grooved], it incurs a fatal violation of ID[grooved] and is eliminated from the competition. While candidate (5d), with a coronal stop, is not grooved, we assume that it does not incur a violation of ID[grooved] because stops are inherently and universally underspecified for the feature [grooved].[5] Fricatives alone license the feature [grooved]. In this instance, a coronal stop is, thus, the preferred substitute for a grooved coronal fricative, even though it violates the lower ranked constraint ID[continuant].

This same ranking of constraints results in a different repair for an input /θ/, as shown in (6). Both coronal fricative candidates (6a) and (6b) are eliminated by their fatal violations of undominated *s and *θ, respectively. This time, the remaining fricative candidate (6c) does not incur a violation of ID[grooved] because the input interdental bears the same specification for the feature [grooved]. The choice between the fricative candidate (6c) and the coronal stop candidate (6d) is made by ID[continuant], yielding candidate (6c) as the winner, even though it violates lower ranked *f and ID[place].

(6) Labialization of interdentals

/θʊrsti	/ 'thirsty'	* s	*θ	ID[grooved]	ID[cont]	*f	ID[place]
a.	sʊti	*!		*			
b.	θʊti		*!				
c. ☞	fʊti					*	*
d.	tʊti				*!		

A slightly different ranking of these same constraints in another child's phonology would result in a single, uniform repair, namely Stopping of all coronal fricatives. Such a repair would fully comply with the conspiracy to avoid coronal fricatives. Consider the data in (7) from Child 181 (age 4;1), who excluded all coronal fricatives from her inventory, replacing them with coronal stops.

(7) Child 181 (age 4;1)

a. Grooved coronal fricatives replaced by coronal stops (Stopping)

[5]Our interpretation here assumes that a stop candidate with any specification (+ or −) for the feature [grooved] is universally ill-formed and, thus, excluded in principle. This constraint can only be violated by corresponding segments with licensed coefficient specifications for the feature [grooved]. Our assumption that fricatives alone license the feature [grooved] is similar to standard assumptions about the feature [anterior] being licensed exclusively by coronals. If the loss of the feature [grooved] in the mapping of a fricative to a stop violates any constraint (e.g. Max[feature]), that constraint must be low-ranked.

[tup] 'soup'	[toʊp] 'soap'
[bʌti] 'bus-i'	[aɪt] 'ice'

b. Interdental fricatives replaced by coronal stops (Stopping)

[tʌti] 'thirsty'	[deɪʔnu] 'thank you'
[titi] 'teeth-i'	[wit] 'wreath'

c. Labial fricatives produced target-appropriately

[fʊt] 'foot'	[feɪ] 'face'
[faɪjʊ] 'fire'	[fɪht] 'fish'

While Stopping of all coronal fricatives can be achieved by various different constraint rankings, the tableaux in (8) show for both types of words that all candidates but the Stopping candidates (8d, h) are eliminated either by the undominated markedness constraints or ID[place].

(8) Stopping of all coronal fricatives

Ranking: *s, *θ ≫ ID[place] ≫ ID[continuant] ≫ *f ≫ ID[grooved]

/sup/ 'soup'		*s	*θ	ID[place]	ID[cont]	*f	ID[grooved]
a.	sup	*!					
b.	θup		*!				*
c.	fup			*!		*	*
d. ☞	tup				*		
/θʌrsti/ 'thirsty'							
e.	θʌti		*!				
f.	fʌti			*!		*	
g.	sʌti	*!					*
h. ☞	tʌti				*		

We will return to the case of Stopping in §4 when we consider the longitudinal development of processes in a conspiracy.

Four other, more narrowly defined instances of this conspiracy also result in a single, transparent repair and require a crucial ranking among the faithfulness constraints. Consider first the data in (9), from Child 153 (age 5;8), who produced grooved coronal fricatives target-appropriately (9a), but replaced interdental fricatives with labial fricatives (9b).

(9) Child 153 (age 5;8)

a. Grooved coronal fricatives produced target-appropriately

[sʌn] 'sun'	[soʊp] 'soap'
[ʤusi] 'juicy'	[bʌs] 'bus'

b. Interdental fricatives replaced by labial fricatives (Labialization)

[fʌm] 'thumb'	[maʊf] 'mouth'
[fʌndoʊ] 'thunder'	[tuf] 'tooth'

c. Labial fricatives produced target-appropriately

[feɪs] 'face'	[wuf] 'roof'
[kɔːfɪŋ] 'coughing'	[lif] 'leaf'

The tableaux in (10) illustrate the faithful realization of target /s/ and the unfaithful realization of target /θ/. In 'sun' words, all unfaithful candidates are ruled out either by a violation of undominated *θ (10b) or by violation of faithfulness constraints, e.g. (10c) and (10d). The fully faithful candidate (10a) is, thus, the optimal output. For input 'thumb' words, however, the fully faithful candidate (10e) is ruled out by its violation of undominated *θ, and the coronal output candidates (10g) and (10h) are eliminated due to their violations of ID[grooved] and ID[continuant], respectively. This results in (10f) as the winner, having only violated lower-ranked *f and ID[place].

(10) Labialization of interdentals & target-appropriate realizations of grooved coronal fricatives

Ranking: *θ ≫ ID[grooved], ID[continuant] ≫ *s, *f ≫ ID[place]

/sʌn/ 'sun'		***θ**	**ID[grooved]**	**ID[cont]**	***s**	***f**	**ID[place]**
a. ☞	sʌn				*		
b.	θʌn	*!	*				
c.	fʌn		*!			*	*
d.	tʌn			*!			
/θʌm/ 'thumb'							
e.	θʌm	*!					
f. ☞	fʌm					*	*
g.	sʌm		*!		*		
h.	tʌm			*!			

Consider now the case of another child with the same restrictions on his fricative inventory, but who employed a different repair. The data in (11) are from Child 17 (age 4;9) and illustrate the process of Grooving as the response to the problem posed by interdental fricatives.

(11) Child 17 (age 4;9)

a. Interdentals replaced by grooved fricatives (Grooving)

[sʌm] ‘thumb’	[sif] ‘thief’
[maʊs] ‘mouth’	[tis] ‘teeth’

b. Grooved fricatives produced target-appropriately

[sʌn] ‘sun’	[soʊp] ‘soap’
[maʊs] ‘mouse’	[dɛs] ‘dress’

c. Labial fricatives produced target-appropriately

[fis] ‘fish’	[faiv] ‘five’
[lif] ‘leaf’	[wuf] ‘roof’

While Child 17 and Child 153 exhibited the same restrictions on their fricative inventories, the constraint hierarchy required for Child 17 differed from that of Child 153 because the repair differed. This point is illustrated by the tableaux in (12). The crucial difference relates to the ranking of ID[place] and ID[grooved]. The higher ranking of ID[place] in the case of Child 17 eliminates the labial fricative candidate for ‘thumb’ words (12f) in favor of the grooved alternative (12g).

(12 Grooving of interdental fricatives and target-appropriate realization of grooved fricatives

Ranking: *θ ≫ ID[place], ID[continuant] ≫ *s, *f ≫ ID[grooved]

/s n/ ‘sun’		***θ**	**ID[place]**	**ID[cont]**	***s**	***f**	**ID[grooved]**
a. ☞	sʌn				*		
b.	θʌn	*!					*
c.	fʌn		*!			*	*
d.	tʌn			*!			
/θʌm/ ‘thumb’							
e.	θʌm	*!					

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/s n/ ‘sun’		*θ	ID[place]	ID[cont]	*s	*f	ID[grooved]
f.	fʌm		*!			*	
g. ☞	sʌm				*		*
h.	tʌm			*!			

Another narrowly defined instance of the typology is illustrated by Child 49 (age 4;4), who produced interdental fricatives target-appropriately (13a), but replaced grooved coronal fricatives with coronal stops (13b).

(13) Child 49 (age 4;4)

a. Interdental fricatives produced target-appropriately

[θʊdi] ‘thirsty’	[θʌndə] ‘thunder’
[maʊθ] ‘mouth’	[diθ] ‘teeth’

b. Grooved coronal fricatives replaced by coronal stops (Stopping)

[dʌn] ‘sun’	[əweɪtʊ] ‘eraser’
[dænə] ‘Santa’	[aɪt] ‘ice’

c. Labial fricatives produced target-appropriately

[faɪv] ‘five’	[gɔfɪn] ‘coughing’
[lif] ‘leaf’	[feɪt] ‘face’

The tableaux in (14) illustrate the unfaithful realization of ‘sun’ words and the faithful realization of ‘thirsty’ words. For ‘sun’ words, the fully faithful candidate (14a) is ruled out by its violation of undominated *s, while the other fricative candidates (14b) and (14c) are eliminated by violations of either ID[grooved] or ID[place]. While candidate (14d) does violate lower-ranked ID[continuant], it is nonetheless selected as the winner. For ‘thirsty’ words, all unfaithful candidates are ruled out by violations of either *s or the faithfulness constraints. The fully faithful candidate (14e) is, thus, selected as optimal.

(14) Stopping of grooved coronal fricatives & target-appropriate realizations of interdentals

Ranking: *s ≫ ID[grooved], ID[place] ≫ ID[continuant] ≫ *θ, *f

/sʌn/ ‘sun’		*s	ID[grooved]	ID[place]	ID[cont]	*θ	*f
a.	sʌn	*!					
b.	θʌn		*!			*	

/sʌn/ ‘sun’		*s	ID[grooved]	ID[place]	ID[cont]	*θ	*f
c.	fʌn		*!	*			*
d. ☞	tʌn				*		
/θʊrsti/ ‘thirsty’							
e. ☞	θʊdi					*	
f.	fʊdi			*!			*
g.	sʊdi	*!	*				
h.	tʊdi				*!		

While Stopping is one attested repair associated with the exclusion of grooved fricatives, some children opt instead to replace grooved fricatives with interdental fricatives by a process of Dentalization. The data in (15) from Child 124 (age 3;1) illustrate this alternative repair.

(15) Child 124 (age 3;1)

a. Grooved fricatives replaced by interdental fricatives (Dentalization)

[θoʊp] ‘soap’	[maʊθ] ‘mouse’
[beɪθbɔl] ‘baseball’	[bʌθ] ‘bus’

b. Interdental fricatives produced target-appropriately

[θif] ‘thief’	[bæθ] ‘bath’
[maʊθ] ‘mouth’	[tuθi] ‘toothy’

c. Labial fricatives produced target-appropriately

[kɔf] ‘cough’	[hæfin] ‘laughing’
[wuf] ‘roof’	[gufi] ‘goofy’

As shown in (16), the constraint hierarchy for this child differs from that of Child 49. The crucial difference relates to the relative ranking of ID[continuant] and ID[grooved]. The higher ranking of ID[continuant] in this instance eliminates candidate (16d) with a stop, allowing candidate (16b) to survive as optimal.

(16) Dentalization of grooved fricatives and target-appropriate realization of other fricatives

Ranking: *s ≫ ID[continuant], ID[place] ≫ *θ, *f ≫ ID[grooved]

/soʊp/ ‘soap’		*s	ID[cont]	ID[place]	*θ	*f	ID[grooved]
a.	soʊp	*!					
b. ☞	θoʊp				*		*
c.	foʊp			*!		*	*
d.	toʊp		*!				
/θif/ ‘thief’							
e. ☞	θif				*	*	
f.	fif			*!		**	
g.	sif	*!				*	*
h.	tif		*!			*	

All of the cases presented above involved error patterns affecting coronal fricatives, and all were consistent with the standard conception that conspiracies result in transparent generalizations. Note, however, that the breadth of the error patterns varied from affecting all coronal fricatives to a more limited effect on a subclass of coronal fricatives. Additionally, there was variation in the number of different repairs that a child might employ. Some of those repairs even yielded other coronal fricatives (e.g. Dentalization and Grooving), in apparent contradiction to the larger coronal fricative conspiracy. Finally, some crucially ranked faithfulness constraints for some children did not always result in multiple repairs within those same children’s phonologies.

3.2 Other related repairs and anomalies

3.2.1 The main problems—We now turn to the two main theoretical problems that are posed by processes that affect coronal fricatives. One problem centers on the proper characterization of the well-documented, but theoretically challenging and controversial counterfeeding interaction between Labialization and Dentalization. The other related problem is to provide for the principled exclusion of the empirically unattested feeding interaction between Dentalization and Labialization. As for the first of these problems, the observed counterfeeding interaction between Labialization and Dentalization results in outputs that are opaque (i.e. the phonetic outputs from Dentalization are superficial exceptions to Labialization). While such opacity is not consistent with standard conceptions of a conspiracy, we suggest that these results are, nonetheless, an instantiation of the same coronal fricative conspiracy illustrated above. That is, two processes with their different repairs are both working together to avoid target coronal fricatives. Each process is compelled by the same markedness constraints that motivated other independently necessary processes associated with the conspiracy as described above. It is simply the interaction of processes (i.e. the constraint hierarchy) that gives this instance of the conspiracy a different complexion. The fact remains that no target coronal fricative was produced correctly as a result of these processes. Consider the representative data in (17) from Child 131 (age 4;8), who exhibited Labialization and Dentalization operating in a counterfeeding relation. The forms in (17a) show that target interdentals did not occur and were replaced by labial fricatives (Labialization), and the forms in (17b) show that grooved coronal fricatives did not occur and were replaced by interdentals. Importantly, derived interdentals did not undergo Labialization.

(17) Child 131 (age 4;8), Counterfeeding interaction

a. Interdentals replaced by labial fricatives (Labialization)

[fʌm] ‘thumb’	[fʌndʊ] ‘thunder’
[maʊf] ‘mouth’	[tuf] ‘tooth’

b. Grooved coronal fricatives replaced by interdentals (Dentalization)

[bʌθ] ‘bus’	[ma θ] ‘mouse’
[aɪθi] ‘icy’	[beɪθbɔ] ‘baseball’

c. Labial fricatives produced target-appropriately

[kɔf] ‘cough’	[wæfin] ‘laughing’
[faɪv̥] ‘five’	[faɪjʊ] ‘fire’

Given the constraints considered thus far, Classic Optimality Theory cannot account for counterfeeding interactions of this sort without encountering a ranking paradox. That is, in the case at hand, *θ would need to be ranked above ID[place] to account for Labialization, but *θ would at the same time also need to be ranked below ID[place] to prevent derived interdentals from undergoing Labialization. This dilemma has prompted several alternative theoretical remedies for the characterization of counterfeeding interactions, including Local Constraint Conjunction (e.g. Moreton and Smolensky, 2002; Smolensky, 1995), Comparative Markedness (e.g. McCarthy, 2002b), Sympathy (e.g. McCarthy, 1999), input-prominence faithfulness (e.g. Jesney, 2007), and Optimality Theory with Candidate Chains (McCarthy, 2007). While any one of these alternative approaches is capable of accounting for the particular counterfeeding interaction between Labialization and Dentalization, we adopt OT-CC for its advantages over the other approaches, as convincingly argued by McCarthy (2007), and, as we will see, for its advantages in explaining some of the anomalies associated with the putative coronal fricative conspiracy.[6] One of those anomalies is the surprising non-occurrence of the feeding interaction between Dentalization and Labialization, which all theories predict should occur. The contributions of OT-CC to these issues are taken up in the following discussion.

3.2.2 The contribution of Optimality Theory with Candidate Chains (OT-CC)—

One of the innovations of OT-CC was the introduction of a new way of conceiving of output candidates, namely ‘candidate chains’, along with a new family of constraints, namely ‘Precedence constraints’. In this framework, each input has a small, finite set of competing output candidates, with each reflecting a highly restricted serial chain of unfaithful mappings from the fully faithful candidate. For a chain to be valid, it must meet three requirements: (i) It must begin with the fully faithful candidate, (ii) each unfaithful serial step of a chain must be minimal (i.e. gradual), and (iii) each serial step of a chain must be harmonically improving based on the language-specific hierarchy. These points can be illustrated by considering the valid chains for the ‘s > θ > f’ chain shift described above. More specifically, the valid chains for an input /s/ would be limited to those schematized in (18), assuming that the faithfulness constraint ID[continuant] is highly ranked (but below *s).

(18) Valid candidate chains for input /s/

- **a.** [s]
- **b.** [s] > [θ]
- **c.** [s] > [θ] > [f]
- **d.** [s] > [t]

Candidate (18a) represents the fully faithful candidate. All valid chains must include (and begin with) the fully faithful candidate. Candidate (18b) reflects a minimal departure from the fully faithful candidate, compelled by the markedness constraint banning grooved coronal fricatives (i.e. *s). Based on the language-specific hierarchy, this unfaithful mapping entails a single, harmonically improving violation of the constraint ID[grooved]. Candidate (18b) would also be the intended winner in a counterfeeding interaction between these processes. Another candidate that is harmonically improving and minimally different from the fully faithful candidate is (18d), which entails a single violation of ID[continuant]. Candidate (18c) builds on candidate (18b) by adding a subsequent ID[place] violation, compelled by the markedness constraint banning interdentals (i.e. *θ). Candidate (18c) would represent the result of a feeding interaction. This is where Precedence (Prec) constraints come into play. Such constraints assign violations to a chain depending on the internal order of its faithfulness violations. For example, the constraint as defined in (19) is a particular instance of a Prec constraint and is relevant to the case at hand. This constraint would assign two violations to candidate (18c) and only one violation to candidate (18b). Candidate (18d) would incur no violations of Prec because it does not violate ID[grooved]. Recall that stops are inherently underspecified for the feature [grooved], and that

[6]While the above cited accounts accept the empirical validity of chain shifts as the result of phonological processes in both developing and fully developed languages, others have maintained that some (if not all) developmental chain shifts can be attributed to either a restricted set of underlying representations, motor limitations, perceptual problems, errors in phonetic transcription (i.e. covert contrasts), or lexical inertia (e.g. Etlinger, 2009; Rose, 2006; Velleman, 1988). Importantly, under this latter view, chain shifts are not the result of active phonological processes. We do not deny the potential role that these factors might play in particular cases. However, imposing restrictions on children’s underlying representations runs counter to Richness of the Base. Also, given Richness of the Base and observed perceptual confusions among the non-sibilant fricatives, it would be important for the hierarchy to ensure the possibility of characterizing attested mergers—no matter what might be assumed about the child’s underlying representations. As regards potential transcription errors due to the transcriber’s failure to detect covert contrasts, the available instrumental acoustic analyses have yielded mixed results. That is, some children who seemingly merge the non-sibilant fricatives have been found to exhibit subtle acoustic differences, while others fail to exhibit those same acoustic distinctions (e.g. Velleman, 1988). Finally, there can be little doubt that fully developed languages exhibit chain shifts of various sorts (e.g. Moreton and Smolensky, 2002). Consequently, in the absence of evidence to the contrary, continuity considerations would suggest that developmental chain shifts should be empirically and theoretically comparable to those evident in fully developed languages. While our theoretical accounts of the phenomena in this paper have relied primarily on typological considerations, the results from acoustic analyses and perceptual studies can also be seen as offering some ‘grounding’ for the constraints/hierarchies that govern chain shifts in both developing and fully developed languages (e.g. Hayes, Kirchner and Steriade, 2004).

ID[grooved] can only be violated by a change in the coefficient specification of the feature (not its absence).

(19) Precedence constraint

Prec(ID[place], ID[grooved]): Every violation of ID[grooved] must be preceded by a violation of ID[place], and it must not be followed by a violation of ID[place][7]

The definition of Prec includes two clauses, either or both of which can assign violations to a candidate chain. The reason candidate (18c) incurs two violations of Prec is, first, because the ID[grooved] violation was not preceded by a mandatory ID[place] violation, and, second, because the ID[grooved] violation was followed by a prohibited ID[place] violation. Candidate (18b) is preferred over (18c) because, while (18b) does incur one violation of Prec for its failure to include an ID[place] violation before its ID[grooved] violation, it at least complies with the second clause of Prec by not having a following violation of ID[place]. If this Prec constraint were ranked high enough in the hierarchy (e.g. above the markedness constraint banning interdental fricatives (*θ), but below both ID[continuant] and the markedness constraint banning grooved coronal fricatives (*s)), it would eliminate the feeding candidate (18c) in favor of the counterfeeding candidate (18b). The required ranking is given in (20) along with generic tableaux for an input /s/ and /θ/. This account fits the schema for other OT-CC accounts of counterfeeding interactions (e.g. McCarthy, 2007).

(20) Counterfeeding chain shift

Ranking: *s ≫ ID[continuant] ≫ ID[grooved] ≫ Prec(ID[place], ID[grooved]) ≫ *θ ≫ ID[place] ≫ *f

	/s/	*s	ID[cont]	ID[grvd]	Prec (ID[place],ID[grvd])	*θ	ID[place]
a.	s	*!					
b. ☞	s > θ			*	*	*	
c.	s > θ > f			*	**!		*
d.	s > t		*!				
	/θ/						
e.	θ					*!	
f. ☞	θ > f						*

As currently conceived, OT-CC, with its permutable constraint rankings, would also erroneously predict that a feeding interaction could occur if the two markedness constraints against coronal fricatives (i.e. *s and *θ) and the faithfulness constraint ID[continuant] were ranked above ID[grooved], as might follow from the default ranking of markedness over

[7]The two faithfulness constraints that make up this Prec constraint are logically independent of one another. First, note that a change in place does not necessarily involve a change in the feature [grooved] (e.g. f > θ or θ > f). Similarly, a change of the feature [grooved] does not necessarily involve a change of place (e.g. s > θ or θ > s). Note, too, that /s/ could change its place in terms of the feature [anterior] without changing its specification for [grooved] (e.g. s > ʃ).

faithfulness in early stages of acquisition (e.g. Smolensky, 1996a). That is, the greater demand to comply with the two undominated markedness constraints and ID[continuant] would override any violations assessed by this particular Prec constraint and would result in all fricatives being realized as [f]. The unattested feeding interaction could, however, be circumvented if ID[continuant] were forced to be ranked lower in the hierarchy under certain circumstances. Our proposed modification to the theory takes advantage of the observation that one of the early, preferred strategies for avoiding target coronal fricatives is to employ Stopping. This suggests that the faithfulness constraint ID[continuant] must be ranked lower among the faithfulness constraints in the initial-state hierarchy in order to achieve this effect. This point is further supported by those children who exclude all fricatives from their inventory (see especially the 41 children cited in Table 3). This is also exactly what might be expected of a conspiracy, namely one or more markedness constraints dominating crucially ranked faithfulness constraints. The putative conspiracy in this instance is to avoid target coronal fricatives. This suggests that there is an initial-state default ranking of ID[continuant] below Prec(ID[place], ID[grooved]). The novelty of our proposal about the default ranking of ID[continuant] is that it begins to expose some of the substantive details about the ranking of certain faithfulness constraints relative to other constraints in initial-state early grammars.[8]

In addition to the default ranking of ID[continuant], a metacondition of OT-CC imposes a further ranking requirement between a specific faithfulness constraint and its associated Precedence constraint (McCarthy, 2007; cf. Kavitskaya and Staroverov, 2010; Wolf, 2008).[9] In this instance, ID[grooved] must outrank Prec(ID[place], ID[grooved]). These ranking requirements, when taken together, result in crucial rankings among faithfulness constraints, which are themselves dominated by a particular markedness constraint, consistent with the standard schema for a conspiracy. This default ranking and the metacondition also have the desired empirical consequence of precluding a feeding interaction when the two markedness constraints against coronal fricatives are undominated. The hierarchy and tableaux in (21) illustrate the Stopping option for coronal fricatives when OT-CC is employed. The candidate chains in this instance differ from those in (20) because the hierarchy is different, and valid chains are determined from the language-specific constraint hierarchy. Note, for example, that for an input /s/, the chain ‘s > θ’ is not a valid chain because it is not harmonically improving according to the hierarchy in (21) and is, thus, excluded from consideration. This chain could, however, be a valid chain if there were some argument for ranking *s over *θ. That chain and the additional hypothetical unfaithful chain ‘s > θ > f’ would, in any event, be eliminated by their violations of ID[grooved].

(21) Stopping of all coronal fricatives

[8]The substance of our proposal is similar to the claim that the family of output-to-output correspondence constraints is by default undominated in the initial-state (e.g. Hayes, 2004). One obvious difference is that we are making a finer grained distinction by specifying the default ranking of particular constraints.

[9]The rationale for this metacondition was intended to limit the role of any given Precedence constraint. More specifically, the metacondition requires that the faithfulness constraint that serves as the second argument of a Precedence constraint is fixed in its ranking over the Precedence constraint (i.e. Faith-B ≫ prec(Faith-A, Faith-B)). The consequence of this requirement is that the Precedence constraint can play a role if and only if the transparent and opaque candidates tie on Faith-B. This metacondition is not unlike other metaconditions that have been proposed within Optimality Theory, e.g. the requirement that a locally conjoined constraint must be ranked over its individual conjuncts.

Ranking: *θ, *s ≫ ID[grooved] ≫ Prec(ID[place], ID[grooved]), ID[place] ≫ ID[continuant]

	/s/	*θ	*s	ID[grvd]	PREC(ID[place],ID[grvd])	ID[place]	ID[cont]
a.	s		*!				
b. ☞	s > t						*
	/θ/						
c.	θ	*!					
d. ☞	θ > t						*
e.	θ > f					*!	

We further suggest that the default ranking of Prec(ID[place], ID[grooved]) over ID[continuant] can be overridden on the basis of positive evidence motivating the demotion of one of the markedness constraints against coronal fricatives below Prec(ID[place], ID[grooved]). This means that ID[continuant] and Prec(ID[place], ID[grooved]) become freely permutable after some learning has taken place regarding coronal fricatives. The ranking in (20) for a chain shift reflects some imperfect (partial) learning about coronal fricatives and is one possible permutation of Prec(ID[place], ID[grooved]) and ID[continuant]. The learning is considered imperfect because, while it does not result in any correct realizations of target coronal fricatives, it does at least yield a fricative for a target fricative, and it introduces a distinction in the behavior of target coronal fricatives that begins to approximate the target. This might reasonably follow from a child's recognition (i) that target fricatives are not stops and must instead have fricative correspondents in the output, and (ii) that there is some further difference between target coronal fricatives that must also be maintained (albeit incorrectly) in the child's output. Current error-driven learning algorithms (e.g. Boersma, 1998; Tesar and Smolensky, 1998) have not yet attempted to provide for imperfect learning of this particular sort, but see Tihonova (2009) for a possible OT-CC alternative. Finally, the progression from the chain shift stage to full faithfulness would require the demotion of *s immediately below ID[grooved], along with the demotion of *θ below ID[place]. Error-driven learning of this sort might reasonably follow in one or more steps from the child's recognition that specifically /θ/ and /f/ contrast and further that /s/ and /θ/ contrast. Support for these propositions is offered below (§4) in our discussion of the life-cycle of a conspiracy.

A distinguishing empirical consequence of our OT-CC account is that it predicts that other logically possible chain shifts should not occur and are therefore excluded on principled grounds. For example, rule-based and other constraint-based theories predict that Stopping of target interdentals and Dentalization of grooved coronal fricatives should be a possible counterfeeding interaction (e.g. 'thumb' [tʌm], 'sun' [θʌn]). However, to our knowledge, no chain shift of this sort has been documented in the literature, nor did any of the 234 children from the Developmental Phonology Archive exhibit this chain shift in their pretreatment phonologies. For an interdental fricative to be realized as a coronal stop, ID[continuant] would have to be ranked below *θ, and ID[place] would be ranked (somewhere) above *θ to eliminate a Labialization candidate, as illustrated in (22). No violations of ID[grooved] (and thus Prec) are relevant to any of the valid chains for input /θ/.

(22) Stopping of interdentals (hypothetical)

Ranking: *s ≫ ID[grooved] ≫ Prec([ID[place],ID[grooved]), ID[place] ≫ *θ ≫ ID[continuant]

	/θ/	*s	ID[grvd]	Prec (ID[place],ID[grvd])	ID[place]	*θ	ID[cont]
a.	θ					*!	
b.	θ > t						*

As shown in (23) for input /s/-words, however, the same ranking of constraints would also favor Stopping (23d), instead of the intended, although hypothetical, Dentalization candidate (23b). More specifically, the fully faithful candidate (23a) would be eliminated by an undominated *s violation. Candidates (23b) and (23c) would both incur one violation of ID[grooved] for the second step in their chains and one additional violation of Prec for not being preceded by and ID[place] violation. Candidates (23b) and (23c) would, thus, be eliminated in favor of the less unfaithful Stopping candidate (23d). It is important to keep in mind that faithfulness violations are cumulative within a chain, but markedness violations are assessed solely on the final element of a chain. Note also that, of the two candidate chains ending in a stop, candidate (23d) is the more harmonic because the change from a fricative to a stop does not result in an ID[grooved] violation. Consequently, for the intended hypothetical winner (23b) designated by ‘ ’ to be selected as optimal in this chain shift, ID[continuant] would have needed to be ranked above *θ, thereby resulting in a ranking paradox. The empirically correct generalization appears to be that, if interdentals undergo Stopping, and if grooved coronal fricatives are also produced in error, the latter class of coronal fricatives must also undergo Stopping.

(23) Stopping preferred over Dentalization

Ranking: *s ≫ ID[grooved] ≫ Prec(ID[place],ID[grooved]), ID[place] ≫ *θ ≫ ID[continuant]

	/s/	*s	ID[grvd]	Prec (ID[place],ID[grvd])	ID[place]	*θ	ID[cont]
a.	s	*!					
b.	s > θ		*!	*		*	
c.	s > θ > t		*!	*			*
d.	s > t						*

3.2.3 Typological evaluation of OT-CC—We now turn to a more critical evaluation of OT-CC by examining the theory’s predictions against the facts of our larger study, which expanded the focus to include those children who excluded labial fricatives from their inventories. As noted earlier, the original Dinnsen, Green, Gierut, and Morrisette (2011) study limited its focus to those 160 children who at least included labial fricatives in their inventories. Recall that this restriction was deemed necessary because labial fricatives were potential products of Labialization and also potential products of a feeding interaction when Dentalization was active. However, errors in coronal fricatives should also be possible when labial fricatives are excluded from the inventory. More specifically, rule-based theories and certain constraint-based approaches predict that it should be possible for another type of chain shift to occur. For example, labial fricatives might be excluded from the inventory and could, in principle, be replaced by interdental fricatives (Coronalization), while target interdentals might also be excluded, being replaced by a grooved coronal fricative (Grooving) (e.g. ‘fun’ [θ n], ‘thumb’ [s m]). We will see shortly that Coronalization and Grooving are each independently necessary processes in some children’s phonologies. Importantly, derived interdentals would not undergo Grooving in this hypothetical reverse chain shift. A reverse chain shift is predicted to be possible in a rule-based framework because it would follow from a counterfeeding interaction between Grooving and Coronalization. To our knowledge, no such chain shift has been documented in the literature, nor did any of the 234 children in the Developmental Phonology Archive exhibit a reverse chain shift in their pretreatment phonologies. Given the constraints considered thus far in this paper, a reverse chain shift would entail a ranking paradox between ID[grooved] and *θ and is correctly precluded, as illustrated in (24).

(24) Unattested chain shift precluded

Ranking: *f ≫ ID[continuant], ID[grooved] ≫ Prec(ID[place], ID[grooved]) ≫ *θ ≫ ID[place] ≫ * s

	/f/	*f	ID[cont]	ID[grvd]	Prec(ID[place],ID[grvd])	*θ	ID[place]	*s
a.	f	*!						
b. ☞	f > θ					*	*	
c.	f > θ > s			*!			*	*
d.	f > p		*!					
	/θ/							
e. ☞	θ					*		
f. ☜	θ > s			*!	*			
g.	θ > t		*!					

For input /f/-words, the ranking of ID[grooved] ≫ *θ predicts the intended hypothetical output for Coronalization (24b), i.e. f > θ. However, for input /θ/-words, the unintended, fully faithful candidate (24e) would be predicted to be optimal. The intended hypothetical winner (24f) would require the paradoxical ranking of *θ ≫ ID[grooved]. This paradox is also reflective of the technical invalidity of this candidate chain and that of (24c) due to the ranking of ID[grooved] over *θ. Similarly, (24g) can be considered technically invalid because of the high ranking of ID[continuant]. This paradox raises a question about one of the unresolved issues for OT-CC, namely whether there are any limits on Precedence constraints and their internal arguments. That is, are all logically possible orderings of unfaithful mappings subject to Precedence constraint violations? For example, OT-CC could, in the absence of any other restrictions, generate this unwelcome and unattested chain shift if a reverse Precedence constraint were admitted into Con as defined in (25).

(25) Reverse Precedence constraint (hypothetical)

Prec(ID[grooved], ID[place]): Every violation of ID[place] must be preceded by a violation of ID[grooved], and it must not be followed by a violation of ID[grooved]

The tableaux in (26) illustrate how OT-CC could generate the unattested result.

(26) Unattested and hypothetical counterfeeding interaction between Coronalization and Grooving

Ranking: *f ≫ ID[continuant] ≫ ID[place] ≫ Prec(ID[grooved],ID[place]) ≫ *θ ≫ ID[grooved] ≫ *s

	/f/	***f**	**ID[cont]**	**ID[place]**	**Prec(ID[grvd],ID[place])**	***θ**	**ID[grvd]**	***s**
a.	f	*!						
b. ☞	f > θ			*	*	*		
c.	f > θ > s			*	**!		*	*
d.	f > p		*!					
	/θ/							
e.	θ					*!		
f. ☞	θ > s						*	*

Given that this hypothetical chain shift appears to be unattested, there would be no motivation for admitting the reverse Precedence constraint into Con. We will see next that another ranking of this reverse Precedence constraint would also have the undesirable consequence of excluding an attested interaction of another sort.

Recall that the predicted feeding interaction between Dentalization and Labialization failed to be attested in the original Dinnsen, Green, Gierut, and Morrisette (2011) study and that our revised OT-CC account correctly precludes that interaction. Interestingly, our account also predicts that a reverse feeding interaction should be possible, and it does, in fact, occur. The data in (27) from Child 144 (age 3;5) illustrate the occurrence of a reverse feeding interaction between Coronalization and Grooving.[10] More specifically, and as shown in (27a), target interdentals did not occur in the inventory and were replaced by grooved coronal fricatives (Grooving). Similarly, labial fricatives did not occur and were also replaced by grooved coronal fricatives (27b), presumably as a result of Coronalization feeding the Grooving process.

[10]A similar case is reported by Dunphey (2006) for a child learning Dutch as the first language.

(27) Child 144 (age 3;5)

a. Interdental fricatives replaced by grooved fricatives (Grooving)

[sʌnʊ] ‘thunder’	[tusi] ‘toothy’
[maʊs] ‘mouth’	[sʌm] ‘thumb’

b. Labial fricatives replaced by grooved fricatives (Coronalization and Grooving)

[saɪjʊ] ‘fire’	[naɪsi] ‘knife-i’
[wis] ‘leaf’	[sʊt] ‘foot’

c. Grooved fricatives produced target-appropriately

[beɪsbɔ] ‘baseball’	[aɪs] ‘ice’
[sæntə] ‘Santa’	[sɔk] ‘sock’

The tableaux in (28) illustrate our account of the reverse feeding interaction. With both labial fricatives and interdental fricatives being excluded from the inventory, it is clear that *f and *θ must be highly ranked. Additionally, with the substitutes being fricatives, ID[continuant] must also be highly ranked in order to preclude the alternative repair of Stopping. Some of the other constraint rankings and the associated candidate chains in this instance warrant comment. First, the change from /f/ directly to [s] in one step, while harmonically improving by this hierarchy, would not be gradual, making it an invalid chain. That is, such an alteration would involve simultaneous changes in both of the features [grooved] and [place]. A feeding interaction would, thus, minimally require the two gradual and harmonically improving chains ‘f > θ’ and ‘f > θ > s’, provided that *f were ranked over *θ. These chains would not be harmonically improving if the two markedness constraints were equally ranked. The ranking argument here differs from conventional ranking arguments in that the dominance relation between these two constraints is not directly observable. The ranking comes to light only because of the architectural demands of what constitutes a valid chain in OT-CC. For an input /θ/, candidate (28a) is ruled out by its violation of *θ. Candidate (28c) is eliminated by its violation of ID[continuant], thus rendering the Grooving candidate (28b) as the winner. For an input /f/, candidates (28d) and (28e) both lose immediately due to their violations of the highly ranked markedness constraints. The Stopping candidate (28g) fatally violates ID[continuant], resulting in the Grooving candidate (28f) as the winner.

(28) Attested reverse feeding interaction between Coronalization and Grooving

Ranking: *f ≫*θ ≫ ID[continuant] ≫ *s ≫ ID[grooved] ≫ Prec(ID[place], ID[grooved]), ID[place]

	/θ/	*f	*θ	ID[cont]	*s	ID[grvd]	Prec(ID[place],ID[grvd])	ID[place]
a.	θ		*!					
b. ☞	θ > s				*	*	*	
c.	θ > t			*!				
	/f/							
d.	f	*!						
e.	f > θ		*!					*
f. ☞	f > θ > s				*	*		*
g.	f > p			*!				

Recall the reverse Prec constraint that we briefly entertained in (25), which had the unwelcome consequence of providing for the occurrence of the hypothetical and unattested reverse chain shift in (26). Interestingly, that same ranking of constraints in (26) would also incorrectly predict that a reverse feeding interaction should not occur, when, in fact, it does. This represents a further typological argument against admitting into Con the reverse Precedence constraint in (25). If these anomalies are indeed systematic, and if the theory's predictions are to be brought into conformity with the available empirical evidence, the Precedence constraints of OT-CC will need to be restricted in some way. An initial step in that direction could be to admit into Con just those Precedence constraints that find empirical support from typological investigations of the sort presented here. While this might seem *ad hoc*, at present, there are no known *a priori* principles that can identify and select valid Precedence constraints from the larger, logically possible (but unattested) set of Precedence constraints. The approach advocated here may ultimately not be so different from those approaches that have employed typological considerations to motivate the universal markedness and faithfulness constraints of fully developed languages within Classic Optimality Theory (e.g. de Lacy, 2006; Prince and Smolensky, 1993/2004). As more investigations of interacting processes in developing and fully developed languages are undertaken, it may become possible to discern higher order principles that govern the set of permissible versus impermissible Precedence constraints. In the meantime, we adopt the conservative position of admitting into Con just those constraints that find empirical support, which, for now, has the desirable consequence of limiting the power of the theory and rendering the claims readily falsifiable. Because we are concerned with typological evidence here, the discovery of just one case study that requires a new, presumably excluded Prec constraint would be sufficient to admit that constraint into Con.

Another logically possible chain shift that seems not to occur would, in rule-based theories, follow from ordering Stopping of interdentals before the process of Coronalization in a counterfeeding relation (e.g. 'thumb' [t m], 'fun' [θ n]). In such a case, a child might produce grooved coronal fricatives correctly, but would exclude labial fricatives and target interdentals from his/her inventory. While these inventory restrictions were indeed attested in 24 of the 234 children from the Developmental Phonology Archive (N.B. Table 3), the associated substitution patterns did not co-occur in any of those children's phonologies, nor, to our knowledge, have they been reported elsewhere in the literature. Again, assuming that the non-occurrence of this hypothetical chain shift is systematic, Classic Optimality Theory properly excludes it because it would entail a ranking paradox between *θ and ID[continuant]. It would, no doubt, be possible to generate this typologically unattested interaction within the original version of OT-CC if another Precedence constraint were admitted into Con, namely Prec(ID[continuant], ID[place]). We, thus, suggest that this overgeneration problem could be avoided if this Precedence constraint were also excluded from Con. Overgeneration problems of this sort further underscore the need for future research to establish on empirical grounds those Precedence constraints that are typologically motivated versus those that are not.

Under another permutation of the constraints that we have considered thus far, an additional prediction is made that adds to the typology of repairs affecting coronal fricatives, namely that it should be possible for all fricatives to be realized as interdental fricatives. This prediction is borne out by Child 78 (age 4;0), as illustrated in (29). More specifically, labial fricatives and grooved coronal fricatives were excluded from the child's inventory and were replaced by interdental fricatives (29a) and (29b), respectively. Interdental fricatives were, moreover, produced correctly (29c).

(29) Child 78 (age 4;0), all fricatives realized as interdentals

a. Labial fricatives replaced by interdentals (Coronalization)

[θæt̚] 'fat'	[naɪθi] 'knife-i'
[kɔθ] 'cough'	[θɪθ] 'fish'

b. Grooved fricatives replaced by interdentals (Dentalization)

[θup] 'soup'	[ʤuθi] 'juicy'
[maʊθ] 'mouse'	[θoʊp] 'soap'

c. Interdentals produced target-appropriately

[θʌm] 'thumb'	[tiθi] 'teethy'
[maʊθ] 'mouth'	[θʊndʊː] 'thunder'

The tableaux in (30) illustrate our account of these facts. The undominated markedness constraints eliminate the fully faithful candidates (30a) and (30d). The Stopping candidates (30c) and (30f) fatally violate ID[continuant], leaving candidates (30b) and (30e) to survive as optimal. Candidate (30b) reflects Coronalization, violating lower ranked ID[place], and (30e) reflects Dentalization, violating ID[grooved].

(30) Coronalization and Dentalization

Ranking: *f, *s ≫ ID[continuant] ≫ *θ ≫ ID[grooved] ≫ Prec(ID[place],ID[grooved]), ID[place]

	/f/	*f	*s	ID[cont]	*θ	ID[grvd]	PREC(ID[place],ID[grvd])	ID[place]
a.	f	*!						
b. ☞	f > θ				*			*
c.	f > p			*!				
	/s/							
d.	s		*!					
e. ☞	s > θ				*	*	*	
f.	s > t			*!				

This case from Child 78 also appears to be related to the coronal fricative conspiracy in several respects. That is, while just a subclass of coronal fricatives was produced in error, the required hierarchy conforms to the schematization for a conspiracy via its crucially ranked faithfulness constraints that are themselves dominated by one or more markedness constraints. It also makes crucial reference to the same constraints involved in the other well supported instances of the coronal fricative conspiracy. Finally, it results in perfectly transparent outputs. The same is true of Child 144's hierarchy with the reverse feeding interaction. Each of the two children also provided crucial support for the independence of attested, but less well documented error patterns associated with the coronal fricative conspiracy. That is, Child 144 evidenced Grooving, and Child 78 evidenced Coronalization. These two processes are opposite repairs for Labialization and Dentalization, respectively, and are triggered by the opposite ranking of constraints, as illustrated in (31).

(31) Opposite repairs with opposite constraint rankings

- **a.** Labialization (e.g. Child 153): *θ, ID[continuant] ≫ ID[place] ≫ *f
- **b.** Coronalization (e.g. Child 78 & Dunphey, 2006): *f, ID[continuant] ≫ ID[place] ≫ *θ
- **c.** Dentalization (e.g. Child 131): *s, ID[continuant] ≫ ID[grooved] ≫ *θ
- **d.** Grooving (e.g. Child 144): *θ, ID[continuant] ≫ ID[grooved] ≫ *s

In one sense, Labialization and Coronalization are different sides of the same coin. Similarly, Dentalization and Grooving are opposite sides of another coin. Both of these situations contribute equally to the putative coronal fricative conspiracy.

3.3 Summary of cross-sectional results

The combined results from the two cross-sectional studies have identified and documented the occurrence of a number of different processes affecting coronal fricatives, as summarized in (32). Some of the attested interactions among these processes fit neatly with standard conceptions of conspiracies. For example, two different instances of the typology yield perfectly transparent outputs and result in the exclusion of all coronal fricatives, i.e. (32a) and (32b). Another attested instance of the typology (32c) shares properties with (32a) and (32b) but is somewhat more controversial in its characterization as a conspiracy. That is, while (32c) results in errors for all target coronal fricatives, the realization of interdentals for target grooved coronal fricatives renders the Labialization process opaque. The hierarchy does, however, entail independently necessary constraints affecting coronal fricatives, and the ranking of those constraints corresponds with the ranking schema for clear cases of conspiracies. Each of the six remaining instances of the typology (32d–i) represents what might be seen as more limited versions of the coronal fricative conspiracy. That is, each results in target-appropriate realizations of some, but not other, coronal fricatives. The persisting error patterns (and, thus, their associated constraint hierarchies) do, nonetheless, result in transparent outputs and employ constraint rankings that are consistent with conspiracies.

(32) Summary of attested error patterns and constraint rankings

a. Stopping of grooved coronal fricatives & Labialization of interdentals (e.g. Child 20):

*s, *θ ≫ ID[grooved] ≫ Prec(ID[place], ID[grooved]) ≫ ID[continuant] ≫ *f ≫ ID[place]

/s/ → [t], /θ/ → [f]

b. Stopping of all coronal fricatives (e.g. Child 181, pretreatment):

*s, *θ ≫ ID[place] ≫ ID[continuant] ≫ *f ≫ ID[grooved] ≫ Prec(ID[place], ID[grooved])

/s, θ/ → [t]

c. Dentalization & Labialization in a Counterfeeding chain shift (e.g. Child 131):

*s ≫ ID[continuant] ≫ ID[grooved] ≫ Prec(ID[place], ID[grooved]) ≫ *θ ≫ ID[place] ≫ *f

/s/ → [θ], /θ/ → [f]

d. Reverse feeding, Coronalization feeds Grooving (e.g. Child 144):

*f ≫ *θ ≫ ID[continuant] ≫ *s ≫ ID[grooved] ≫ Prec (ID[place], ID[grooved]), ID[place]

/f, θ/ →[s]

e. Coronalization of labial fricatives & Dentalization of grooved coronal fricatives (e.g. Child 78):

*f, *s ≫ ID[continuant] ≫ *θ ≫ ID[grooved] ≫ Prec(ID[place], ID[grooved]), ID[place]

• /f/ → [θ], /s/ → [θ]

f. Stopping of grooved coronal fricatives & target-appropriate interdentals (e.g. Child 49):

*s ≫ ID[grooved] ≫ Prec(ID[place], ID[grooved]), ID[place] ≫ ID[continuant] ≫ *θ, *f

/s/ → [t], /θ/ → [θ]

g. Labialization of interdentals & target-appropriate realizations of grooved coronal fricatives (e.g. Child 153):

*θ ≫ ID[grooved] ≫ Prec(ID[place], ID[grooved]), ID[continuant] ≫ *s, *f ≫ ID[place]

/θ/ → [f], /s/ → [s]

h. Grooving of interdentals & target-appropriate realization of grooved coronal fricatives (e.g. Child 17)

*θ ≫ ID[continuant], ID[place] ≫ *s, *f ≫ ID[grooved] ≫ Prec(ID[place], ID[grooved])

/θ/ → [s], /s/ → [s]

i. Dentalization of grooved fricatives & target-appropriate realization of interdentals (e.g. Child 124)

*s ≫ ID[continuant], ID[place] ≫ *θ, *f ≫ ID[grooved] ≫ Prec(ID[place], ID[grooved])

/s/ → [θ], /θ/ → [θ]

In addition to the attested interactions above, the cross-sectional results from these 234 children (as well as those from other published reports) have failed to establish the occurrence of any of the logically possible interactions in (33). Importantly, our proposed restrictions on OT-CC provide for the attested instances of the typology in (32), while also providing for the principled exclusion of the logically possible, but unattested interactions in (33). More specifically, the exclusion of the feeding interaction (33a) was argued to follow from our proposed default ranking of ID[continuant] below Prec(ID[place], ID[grooved]) when the markedness constraints against coronal fricatives were undominated. The various other unattested counterfeeding interactions (33b-d) followed from limits on admissible Prec constraints. It is, of course, always possible that one of the unattested interactions from (33) could come to light in some other as yet unidentified child's phonology. If that were to happen, some of our proposed restrictions would likely need to be relaxed. For example, if one of the hypothetical counterfeeding interactions in (33) were to occur, it might be necessary to admit into Con one of the Prec constraints that we had otherwise rejected. In such a case, the increase in descriptive power would at least be necessitated on empirical grounds. Until then, we stand by the more constrained characterization of interactions.

(33) Summary of logically possible, but unattested interactions

a. Feeding interaction between Dentalization & Labialization: /s/ → [f], /θ/ → [f]

b. Reverse chain shift involving Cornalization & Grooving: /f/ → [θ], /θ/ → [s]

c. Dentalization and Stopping chain shift: /s/ → [θ], /θ/ → [t]

d. Coronalization and Stopping chain shift: /f/ → [θ], /θ/ → [t]

Taken together, these cross-sectional findings suggest that the instantiations of a conspiracy can differ along several dimensions. That is, they can differ not only in their repairs, but also in the scope of those repairs. For example, (32a–c) effect different repairs, but the scope of those repairs includes all coronal fricatives. The various repairs in (32d–i) also differ, but the scope of those repairs is more limited, affecting a smaller subclass of coronal fricatives. Each instance of the typology in (32) would seem to reflect different amounts of learning on the part of a child. For example, while all target coronal fricatives are produced in error in (32a–c), the child with a hierarchy like that in (32c) would seem to have learned at least that all target coronal fricatives must be differentiated from one another and that they must be realized as fricatives. This appears to be more advanced than a child who produced all coronal fricatives as undifferentiated coronal stops (32b). Along these same lines, the hierarchy in (32a) might be considered to represent a level of knowledge about the target language that is between that of (32b) and (32c). Children with the hierarchies in (32d–i) reflect yet other levels of learning in their error patterns, but they show even greater knowledge with their target-appropriate realizations of some coronal fricatives. While each of the hierarchies in (32d–i) represents differential knowledge about the target language, it is less clear that that knowledge could be rank ordered in terms of learning. Stated differently, instances of the typology in (32d–i) do not seem to depend on one another. While these conjectures are plausible, the actual trajectory of learning cannot be discerned on the basis of cross-sectional data alone. To gain some insight into the life-cycle of a conspiracy, longitudinal evidence is needed that tracks the phonological development of a child who exhibits one of the instantiations of the putative conspiracy. The next section considers the phonological development of Child 181, who was described earlier in (7) and presumably represented a relatively early phase of development.

4. The life cycle of a conspiracy

Recall the pretreatment data in (7) from Child 181 (age 4;1), who produced all coronal fricatives as stops. Following that initial assessment, and as part of a larger experimental study (not related to conspiracies or the error patterns considered here), this child was enrolled in a clinical treatment experiment that was designed to suppress her Gliding 10error pattern by teaching her a liquid consonant for her glide substitutes. For details about the structure of these treatment experiments, see Gierut (2008a). The larger experimental study called for each child's entire phonology to be reassessed at multiple, pre-established intervals during and following treatment, using the same extensive word list that had been used to establish the pretreatment phonology. The words on this list were never used as treatment stimuli. The various sampling intervals afforded an opportunity to observe and document changes, if any, in the child's phonology over time.

The longitudinal analyses for this child identified four distinct stages of development, each of which corresponded with one of the attested typological possibilities in the cross-sectional study. While Child 181 exhibited Stopping of all coronal fricatives at the first interval (age 4;1), her phonology exhibited a change three months later at a pre-established interval during treatment. That is, Stopping began to be suppressed, with interdental fricatives being produced instead as labial fricatives, as shown in (34a). Target grooved coronal fricatives continued to be produced as stops at that point in time (34b). Importantly, while the realization of the error patterns changed at this point in time, all coronal fricatives continued to be produced in error.

(34) Child 181 (age 4;4)

a. Interdental fricatives realized as labial fricatives (Labialization; Stopping partially suppressed)

[fʌm] 'thumb'	[fʌndʊ] 'thunder'
[wifi] 'wreath-i'	[maʊf] 'mouth'

b. Grooved coronal fricatives produced as coronal stops (Stopping)

[tup] 'soup'	[toʊp] 'soap'
[duti] 'juicy'	[aɪti] 'icy'

c. Labial fricatives produced target-appropriately

[fʊt] 'foot'	[naɪfi] 'knife-i'
[wʊfi] 'roof-i'	[wæf] 'laugh'

After treatment ceased, and approximately one month from the prior sampling interval, another important change occurred in the child's phonology, as shown in (35). More specifically, the more limited version of Stopping was suppressed and was replaced by another error pattern, namely Dentalization of grooved coronal fricatives (35a). Labialization of interdentals persisted (35b). This resulted in the emergence of a chain shift with the introduction of opacity. Again, all target coronal fricatives were produced in error, although a coronal fricative was produced as a substitute for another coronal fricative.

(35) Child 181 (age 4;5)

a. Grooved coronal fricatives replaced by interdental fricatives (Dentalization; Stopping fully suppressed)

[θup] 'soup'	[θænə] 'Santa'
[beɪθba] 'baseball'	[maʊθ] 'mouse'

b. Interdental fricatives replaced by labial fricatives (Labialization)

[fʌm] 'thumb'	[fʌndə] 'thunder'
[tifi] 'teeth-i'	[tuf] 'tooth'

c. Labial fricatives produced target-appropriately

[faɪv] 'five'	[læfin] 'laughing'
[ɛʊfɪnt] 'elephant'	[lif] 'leaf'

Approximately one month later at the final sampling interval, the realization of target grooved coronal fricatives changed again, beginning to be produced target-appropriately (36a). However, Labialization of interdental fricatives persisted (36b).

(36) Child 181 (age 4;6)

a. Grooved coronal fricatives produced target-appropriately (Dentalization suppressed)

[sat] 'sock'	[sænə] 'Santa'
[dʒusi] 'juicy'	[aɪs] 'ice'

b. Interdental fricatives produced as labial fricatives (Labialization)

[fʌm] 'thumb'	[fʌndʊ] 'thunder'
[maʊfi] 'mouth-i'	[wif] 'wreath'

c. Labial fricatives produced target-appropriately

[faɪjʊ] 'fire'	[lifi] 'leaf-i'
[læf] 'laugh'	[naɪf] 'knife'

The developmental trajectory of change in Child 181's phonology is especially revealing because it exhibited four different instantiations of the cross-sectional typology at each of the above intervals. Importantly, the child's trajectory supported our conjectures about differences in relative knowledge of the target system. Additionally, from the cross-sectional results, we saw that the first sampling interval for several other children corresponded to what would have been one of Child 181's later stages of development. Their subsequent development was also consistent with Child 181's trajectory. For example, none of these children's subsequent sampling intervals evidenced a presumed reversal, namely a change to Stopping of all coronal fricatives (e.g. Child 181's earliest documented stage of development). Additionally, if changes occurred in these children's realizations of coronal fricatives in later sampling intervals, those changes corresponded with either one of Child

181's later stages of development or resulted in target-appropriate realizations of coronal fricatives.

We are not suggesting that Child 181's trajectory represents the only path of development leading to target-appropriate realizations. It is possible, even likely, that some children might skip some or all of the intermediate steps along the way, or that we might simply fail to observe one of the extant stages of development. Many different factors could contribute to this void, including the timing of sampling intervals, the amount and type of exposure that the child has to relevant data about the target language, and/or the child's own learning strategies. We would, however, not expect a child to exhibit a significant reversal of this trajectory. A significant reversal might be taken as one that regressed by two or more steps along the trajectory. For example, we would not expect a child to exhibit a counterfeeding interaction at an early stage and then revert back to a stage with uniform Stopping of all coronal fricatives. Admittedly, the stronger claim would be to exclude any reversals, including even those as small as a single step backward on the trajectory. However, such a strong claim would have to be reconciled against observed variation that occurs between adjacent developmental stages due possibly to variable constraint rankings in the transition from one stage to another (e.g. Boersma, 1998).

5. Discussion

The proposals and analyses put forward in this paper raise a number of issues and questions that warrant discussion and further study. More specifically, one of those issues relates to our observation that there appear to be no legitimate cases of a feeding interaction between Dentalization and Labialization resulting in the replacement of all coronal fricatives with labial fricatives. A published case study (Barlow, 2007) describes what might be thought to constitute an exception to this claim, but we argue in §5.1 that a very different set of processes is responsible for the facts of the case. Another issue that arises is whether there are other developmental conspiracies that exhibit some of the same anomalies associated with the putative coronal fricative conspiracy. We address this and the related issue of the connection between developmental and diachronic conspiracies in §5.2. Finally, in §5.3, we highlight some limitations of the current study along with other, as yet, unresolved issues relating to opacity effects and typological anomalies in young children's developing phonologies.

5.1 An apparent exception

The published case study of Child Z (male, age 3;0) as described by Barlow (2007) might, at first blush, be thought to represent a counterexample to our typological claim that there are no attested cases of a transparent feeding interaction between Dentalization and Labialization, leading to the replacement of all fricatives with [f]. While this child did replace all coronal fricatives with [f], we will show that this particular result follows from other independently motivated processes involving a constraint hierarchy quite different from those considered in this paper. There are two important empirical characteristics to keep in mind that distinguish this case from the superficially similar, but unattested, substitution pattern. The first difference was brought to light by Barlow in her discovery that Child Z's substitution pattern crucially resulted in opaque, rather than transparent, output representations. Importantly, the observed opacity effect was unlike the opacity associated with a chain shift, requiring some mechanism outside of the empirical domain of OT-CC for an account. The particular type of opacity evidenced by Child Z corresponded with what has been described in rule-based terms as ‘nonderived environment blocking’ (e.g. Kiparsky, 1976) or, in optimality theoretic terms, as a ‘grandfather effect’ (e.g. McCarthy, 2002b). For her optimality theoretic account of the grandfather effect, Barlow appealed to the particular mechanism of ‘Comparative Markedness’ (e.g. McCarthy, 2002b).[11] The second empirical difference was that Child Z’s error pattern operated on both stops and fricatives, whereas the unattested pattern would have been limited to fricatives. With these facts in mind, we reformulate the account, incorporating Comparative Markedness with OT-CC. The rationale for this integrated account is to facilitate comparison with the other analyses presented in this paper and to show that the OT-CC account is not compromised by the facts of this case. While OT-CC is not necessary here, we are still able to take advantage of Barlow’s general insights and employ many of the same constraints.

By way of review, Barlow focused on a general intervocalic weakening process, which essentially banned all but labial consonants in intervocalic position. This process yielded [f] as the substitute for intervocalic coronal fricatives (e.g. [nʌfɪn] ‘nothing’, [tɪfɪn] ‘kissing’). The tableau in (37) provides a preliminary OT-CC account. More importantly, this process also replaced coronal and dorsal stops with [f] in that same context (e.g. [hæfi] ‘hat (dim.)’, [tɑfi] ‘chalk (dim.)’). See the tableau in (38) for an illustration of our account of intervocalic coronal stops. Barlow also introduced a Comparative Markedness constraint (abbreviated here as $_{\mathrm{N}}$*p) to account for the observed opacity effect, specifically a grandfather effect, which rendered intervocalic target labial stops immune to the intervocalic weakening process and which also prevented labial stops from being the ultimate substitute for the other intervocalic consonants. This means that labial stops were realized target-appropriately in intervocalic position (e.g. [fʌpə] ‘zipper’), but labial stops were never the substitute for any of the other consonants in that context. Our reanalysis similarly employs Comparative Markedness to capture the observed grandfather effect for intervocalic labial stops.

The absence of coronal fricatives from Child Z’s inventory can be seen to follow from the two now familiar, highly ranked markedness constraints *θ and *s. Given the OT-CC architectural requirement that a valid candidate chain must be both gradual and harmonically improving, the challenge is to identify a hierarchy and candidate set that would result in the eventual mapping of /s/ (and /θ/) to [f]. The mapping of /θ/ to [f] is not probative and can, thus, be set aside because, under any account, the simple change in place would be both gradual and harmonically improving. However, for target /s/, any conceivable chain involving a change from /s/ to [θ], while gradual, would not be harmonically improving due to the high ranking of *θ. Such chains are consequently invalid and can be discarded from

[11]The innovation of Comparative Markedness was to split each conventional markedness constraint into two disjoint (complementary) sets: one that assigns a violation to a marked structure that is ‘old’, i.e. shared with the fully faithful candidate ($_{\mathrm{O}}$M), and another that assigns a violation to the same marked structure when it is ‘new’ or derived, i.e. not shared with the fully faithful candidate ($_{\mathrm{N}}$M). Comparative Markedness constraints are assumed to be permutable in their ranking. Grandfather effects are schematized by the ranking $_{\mathrm{N}}$M ≫ FAITH ≫ $_{\mathrm{O}}$M. Different rankings of these constraints would also provide for feeding interactions, counterfeeding interactions, and full faithfulness. Comparative Markedness clearly overlaps with OT-CC in many of its predictions about the interaction of processes. Overlap of this sort is obviously undesirable and will ultimately need to be eliminated, but the important point is that OT-CC says nothing one way or the other about the occurrence or characterization of grandfather effects.

consideration. Drawing on our earlier typological observation that the default repair for many children who exclude coronal fricatives from their inventories is to employ Stopping, we might consider the first step away from /s/ in a chain to be a coronal stop [t], which would follow from lower ranked ID[continuant] (i.e. candidate chain (37b)). The fact is that coronal stops were permissible outputs, at least word-initially, although they never served as actual substitutes for any fricatives. We will return to this point shortly. The dominated character of ID[continuant] is further supported by the fact that this child also changed target coronal and dorsal stops to a fricative in intervocalic position. A valid chain ending in a coronal stop (whether underlying or derived from Stopping), however, cannot survive as optimal given Barlow's proposed intervocalic Weakening process, which essentially prohibits all places and manners of articulation in that context, except for labials. Consequently, another valid, but suboptimal, competitor chain that builds on candidate (37b) must change [t] to [p], as illustrated with candidate (37c). This step of the chain is valid because it entails a single change in place, and because it results in an improvement. That is, labial stops did at least occur in both intervocalic and word-initial positions, although derived labial stops never occurred phonetically. This latter point was Barlow's justification for introducing a Comparative Markedness constraint that banned labial stops that differed from the fully faithful candidate (abbreviated here as $_N$*p). Finally, the optimal candidate chain builds on candidate (c) by changing the [p] to [f], as illustrated with candidate (37d). Interestingly, the winning candidate resembles a 'Duke-of-York gambit' (e.g. Baković, 2011; McCarthy, 2003; Pullum, 1976) in that a coronal fricative first changes to a stop and then back again to a fricative, albeit with a different place relative to the input.

(37) Replacement of intervocalic /s/ with [f]

*VtV: Coronals are banned intervocalically[12]

$_N$*p: Labial stops that differ from the fully faithful candidate in terms of any feature(s) are banned

/…s…/		***s, *θ**	***VtV**	**$_N$*p**	**ID[pl]**	**ID[cont]**
a.	s	*!	*			
b.	s > t		*!			*
c.	s > t > p			*!	*	*
d. ☞	s > t > p > f				*	

(38) Replacement of intervocalic /t/ with [f]

/…t…/		***s, *θ**	***VtV**	**$_N$*p**	**ID[pl]**	**ID[cont]**
a.	t		*!			

[12]Barlow formulated this constraint differently, i.e. as an abbreviation for a collection of constraints that banned various intervocalic sounds and that incorporated a labial repair. Our reformulation limits the constraint to a ban on intervocalic coronals, leaving it to the hierarchy to yield the repair.

/…t…/		*s, *θ	*VtV	$_{N}$*p	ID[pl]	ID[cont]
b.	t > p			*!	*	
c. ☞	t > p > f				*	*

As should now be evident from the account above, Child Z's realization of [f] for target /s/, while superficially similar to one aspect of the hypothetical, unattested pattern, is quite different both in terms of the forces that drive it and its resultant opacity effect. It, thus, cannot be taken as a true counterexample to our claim. In fact, this case provides further support for our contention that ID[continuant] must, by default, be ranked low in the hierarchy when *s and *θ are undominated. Finally, it has been useful to reconsider the case of Child Z in terms of an OT-CC account because it revealed a Duke-of-York derivation. Reconsideration of this case has also underscored the empirical character of our various proposals and the value of looking beyond children's superficial substitution patterns in the evaluation of phonological claims.

While OT-CC on its own fails to predict the occurrence of grandfather effects such as that in Child Z's phonology, that could in certain other instances be seen as a desirable consequence. Consider, for example, the three logically possible grandfather effects schematized in Table 4 with their predicted phonetic realizations from the processes that have been the main focus of this paper.

Each of these grandfather effects is predicted to occur by Comparative Markedness or by other mechanisms such as local constraint conjunction (e.g. Łubowicz, 2002). Interestingly, however, the results from our cross-sectional analyses of the 234 phonologies in the Archive failed to support those predictions. We are, moreover, not aware of any published studies that report patterns like those in Table 4. A common property of the unattested possibilities in Table 4 is that underlying target interdental fricatives would be protected from some process (i.e. Labialization, Grooving, or Stopping), while derived interdentals (i.e. those derived from Dentalization or Coronalization) would undergo that process. The non-occurrence of these grandfather effects is obviously not a problem for OT-CC, but other mechanisms designed to handle grandfather effects would need to be constrained in some way to exclude these unattested possibilities. Unfortunately, space limitations prevent us from pursuing those restrictions here. In any event, when we add the unattested grandfather effects from Table 4 to the other set of unattested interactions in (33), it becomes difficult to ignore that so many of the logically possible interactions among error patterns involving coronal fricatives seem not to occur. We take the non-occurrence of those interactions to be systematic (i.e. non-accidental), especially when the results from two comparable typological investigations of other interacting error patterns are weighed against the anomalies identified in this paper. More specifically, one of those studies examined the possible versus attested interactions of Deaffrication and Consonant Harmony in the phonologies of 230 children with phonological delays and found that all of the logical possibilities occurred (Dinnsen, Gierut, Morrisette, Green, & Farris-Trimble, 2011). These facts are discussed in more detail in §5.2 in connection with another conspiracy. The other study similarly examined the possible versus attested interactions of Velar Fronting and Labial Harmony in the sound systems of 235 children with phonological delays and found that the two processes also interacted in all logically possible ways (Dinnsen, Green,

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Morrisette, & Gierut, 2011). These other studies, with comparable methods and numbers of participants, give us confidence that our sample is sufficient to reveal the various logical possibilities, if they were to occur. The fact that they do not occur must at least be taken seriously.

5.2 Other developmental conspiracies

The counterfeeding opacity associated with the putative coronal fricative conspiracy does not appear to be an isolated phenomenon. For example, Dinnsen and Farris-Trimble (2008a) identified the case of a child with a phonological delay, Child 5T (age 4;3), who exhibited a similar opacity effect in a conspiracy with four different repairs that worked together to achieve the same end, namely the avoidance of place and manner distinctions in word-initial position. The repairs included: Stopping (e.g. [tup] 'soup'), Velar Fronting (e.g. [ti] 'key'), Deaffrication (e.g. [tu] 'chew'), and Consonant Harmony (e.g. [ɡɔɡ] 'dog'). Consonant Harmony was considered part of that conspiracy because the occurrence of a marked velar consonant in word-initial position was tolerated if and only if licensed by the trigger of assimilation. While it might seem odd, at least from the perspective of fully developed languages, to merge these distinctions in the presumably strong context of word-initial position, it has been argued elsewhere (e.g. Dinnsen and Farris-Trimble, 2008b, 2009) that children assign prominence to final position in the earliest stages of development, and only later shift prominence to initial position (cf. Inkelas and Rose, 2007). Under this view, the merger of place and manner distinctions in word-initial position would appear to be a developmental mirror-image reflection of the CodaCondition in fully developed languages (e.g. Itô, 1986). The case of Child 5T is, however, interesting in another respect. That is, Deaffrication and Consonant Harmony were found to participate in a counterfeeding interaction, yielding opaque outputs (e.g. [tik] 'cheek', [ɡɔɡ] 'dog'). As we have noted, conspiracies are generally thought to yield transparent outputs. To situate this case in a larger context, a follow-up investigation was undertaken to document the typological occurrence and interaction of Deaffrication and Consonant Harmony in a cross-sectional and longitudinal study including 230 young children with phonological delays (Dinnsen, Gierut, Morrisette, Green and Ferris-Trimble, 2011). It was found that, when these processes co-occurred in a child's phonology, they interacted in all logically possible ways, including a feeding interaction (e.g. [tu] 'chew', [kik] 'cheek', [ɡɔɡ] 'dog'), a grandfather effect (e.g. [tu] 'chew', [kik] 'cheek', [dɔɡ] 'dog'), and a counterfeeding interaction, as with Child 5T. The longitudinal results from that study also revealed a developmental trajectory that placed the transparent feeding interaction at the earliest documented stage, followed by the emergence of opacity due to either a counterfeeding interaction or a grandfather effect, which in turn was followed by the suppression of Deaffrication and/or Consonant Harmony. Importantly, the putative conspiracies discussed in this paper shared emergent opacity effects in the course of their developmental demise. Additionally, our proposed restrictions on OT-CC do not preclude any of the observed typological consequences of the word-initial weakness conspiracy. There is, however, one important difference in the characterization of the word-initial weakness conspiracy: The observed feeding interaction would follow from the default ranking of markedness over faithfulness and a low ranked Precedence constraint. For an OT-CC account of the counterfeeding interaction, see Dinnsen and Farris-Trimble

(2008a), and for an illustrative Comparative Markedness account of the grandfather effect, see Dinnsen (2008).

The course of a developmental conspiracy appears to proceed along much the same path followed by conspiracies that emerge from historical sound changes. The superficial difference is the direction of change. More specifically, Kiparsky (1971, 1976) and Crist (2001) have documented cases of historical sound changes in which transparent conspiracies have emerged from earlier stages of the language that had exhibited marked representations and/or opaque generalizations. This has been attributed to a general preference for change in the direction of transparency and the presumed difficulty of learning marked representations and opaque generalizations. We have seen that children begin with unmarked outputs and transparent generalizations and gradually acquire more marked outputs and opaque generalizations, until target faithfulness is achieved (if at all). These opposite directions of change follow roughly from the same optimality theoretic pressures, namely the default ranking of markedness over faithfulness in the initial-state (e.g. Smolensky, 1996a) and a general constraint demotion algorithm for learning (e.g. Boersma, 1998; Tesar and Smolensky, 1998). The diachronic emergence of a conspiracy is, thus, a consequence of the acquisition process and a series of generational failures to demote the relevant markedness constraints to a position in the hierarchy that would match that of the target language. Whether we are looking at diachronic or developmental conspiracies, the fact remains that opacity effects emerge naturally in the course of learning and sound change.

5.3 Limitations and other unresolved issues

The abundance of opacity effects in early phonological development is striking, especially given the presumed difficulty of learning such generalizations. However, to our knowledge, no experimental study of a naturally occurring language has attempted to evaluate the ease/difficulty of learning an opaque generalization that is target-appropriate for that language. Additionally, we know of only one experimental study that has attempted to induce an opaque generalization as an intermediate stage in the course of acquiring English (Dinnsen, Gierut and Farris-Trimble, 2010), and the findings from that study showed that teaching a child certain word-shapes of English readily introduced both a grandfather effect and a counterfeeding interaction prior to the child's suppression of the associated processes. Finally, if opacity effects were hard to learn, why has it been so difficult for clinicians to eradicate chain shifts in the speech of young children with phonological delays (e.g. Morrisette and Gierut, 2008)? The resistance of chain shifts to remediation suggests that those opacity effects may represent relatively stable states, similar to the presumed stability of transparent generalizations.

While the current paper expanded its focus beyond the earlier study to include a wider range of error patterns affecting coronal fricatives, it also remained limited to just those repairs that involved feature-changing processes. For example, another possible repair complying with the ban on coronal fricatives might have been to delete the offending segments. We did not attempt to document the prevalence of this process relative to the coronal fricative conspiracy, but we did observe some instances of this repair and suspect that Deletion might have been more prevalent for younger children who omitted a variety of consonants due to the default lower ranking of Max. It is, thus, possible that a stage of development involving Deletion preceded a stage involving general Stopping. That hypothetical stage would have bled processes such as Stopping, Dentalization, Labialization, etc., yielding transparent outputs. Deletion is, thus, another possible repair that would be entirely compatible with our characterization of the coronal fricative conspiracy. For further discussion of the theoretical implications of Deletion, especially in early stages of phonological development, see Farris-Trimble (2008).

The general findings from this paper have also raised questions about the range of possible versus attested interactions among other phonological processes in both developing and fully developed languages. As more typological facts of this sort are established, it may be possible to further evaluate our proposed restrictions and to discover new anomalies that support similar theoretical restrictions. For example, future studies might want to extend this survey to other languages and a larger set of children (normal and disordered). However, given the paucity of available data and the difficulty of amassing a database as large and as comprehensive as that consulted for the current study (234 children), it may be equally important to look to individual case studies, which can serve as powerful evaluations of these and other claims—case in point being Child Z (Barlow, 2007), described in §5.1.

The results from this study have also challenged certain standard conceptions of conspiracies and suggest that a conspiracy might be better understood as a highly constrained set of developmental steps along a trajectory with transparent unfaithfulness at one end and full faithfulness at the other. Counterfeeding opacity effects would, thus, be seen as one of several possible outcomes in the course of a conspiracy's life-cycle. If we are correct, learning algorithms will want to provide for the natural emergence of counterfeeding opacity, especially in those languages that do not exhibit the opaque generalizations. One possible approach to the problem might be to allow constraint demotion to be triggered simply by a child's recognition that the perceived form does not match his/her current winner. This does not necessarily mean that the child must fully and accurately recognize how the perceived form differs from the previously produced form, as has been required under currently available algorithms (e.g. Boersma, 1998; Pater 2004; Prince and Tesar, 2004; Smolensky, 1996b; Tesar and Smolensky, 1998). Instead, what seems to be called for here is a more limited type of recognition. That recognition might be guided by the child's current constraint hierarchy and the associated set of candidate chains. That is, when children detect a difference between their prior winner (i.e. their previously produced form) and the heard form, they opt for the next most similar (i.e. shorter) chain as the new winner. The opaque chain in a counterfeeding interaction will always be shorter than the transparent candidate, i.e. incur one less unfaithful mapping and will, thus, more closely resemble the fully faithful candidate. Consequently, the tendency might be that children's recognition would proceed gradually, but in a direction that approaches full faithfulness. A proper evaluation of these conjectures is obviously beyond the scope of this paper and must await more details of how such an algorithm might be implemented and integrated with other emergent opacity effects (e.g. overaplication counterbleeding interactions). For a survey of various developmental opacity effects, see Dinnsen (2008).

6. Conclusion

Cross-sectional and longitudinal evidence has been presented documenting the occurrence, non-occurrence, and interaction of various error patterns affecting young children's acquisition of coronal fricatives in English. The different repairs within and across children yielded a typology that in many respects resembled a conspiracy. Each instance of the putative conspiracy worked to avoid coronal fricatives to some extent. However, some of the novel aspects of this conspiracy included the unexpected absence of a transparent feeding interaction and the occurrence of an opaque counterfeeding interaction. While the typological anomalies fell outside standard conceptions of conspiracies, each documented instance of the typology could be placed on a naturally occurring developmental trajectory, which progressively limited the conspiracy, leading to its ultimate suppression. Taken together, these results suggest that conspiracies arise naturally in early stages of development from an initial-state that is unmarked and transparent, as evidenced by a single uniform repair of all sounds in a general class (e.g. Stopping of all coronal fricatives). As the conspiracy begins to succumb to the pressures of the target language, multiple (non-uniform) repairs begin to emerge. Those repairs can result in transparent or opaque generalizations (e.g. Labialization of interdentals with either Stopping or Dentalization of grooved coronal fricatives). Subsequent developmental instantiations of the conspiracy can emerge with a narrower scope, affecting a subset of the coronal fricatives with a complementary class of these fricatives being produced target-appropriately. The developmental trajectory of this conspiracy can be seen as a mirror-image reflection of the historical emergence of conspiracies, offering some insight into the life-cycle of a conspiracy.

Our account of these facts was argued to follow from proposed restrictions on OT-CC that were intended to limit the power of the theory. The proposed restrictions were of two types: First, ID[continuant] was argued to be ranked by default below Prec(ID[place], ID[grooved]) in the initial state. This restriction had the consequence of precluding the unattested feeding interaction involving Dentalization and Labialization in those cases in which the markedness constraints against all coronal fricatives are undominated. Second, the various logically possible, but unattested counterfeeding interactions were precluded by stipulative limits on the set of permissible Prec constraints in Con. While we do not presume to have an explanation as yet for why some, but not other, Prec constraints are legitimate, we hope that the results from this study begin to establish the fact that at least some Prec constraints may not be necessary on typological grounds. Additional research is called for that evaluates these proposals against the typological facts of other interacting processes in English and other languages.

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Table 1

Predicted outputs from interactions of Dentalization and Labialization

	'fun'	**'thumb'**	**'sun'**
Counterfeeding	[fʌn]	[fʌm]	[θʌn]
Feeding	[fʌn]	[fʌm]	[fʌn]

Table 2

Predicted outputs from interactions of Coronalization and Grooving

	'fun'	**'thumb'**	**'sun'**
Counterfeeding	[θʌn]	[sʌm]	[sʌn]
Feeding	[sʌn]	[sʌm]	[sʌn]

Table 3

Typology of Children's Fricative Inventories

/f/	/θ/	/s/	Total N
			41
x			20
	x		4
		x	24
x	x		22
x		x	112
	x	x	5
x	x	x	6

The occurrence of a particular class of target fricatives is indicated by an 'x' in the corresponding cell. A blank cell indicates the non-occurrence of a class of target fricatives.

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Table 4

Unattested grandfather effects

	'fun'	**'thumb'**	**'sun'**
Dentalization & Labialization	[fʌn]	[θʌm]	[fʌn]
Coronalization & Grooving	[sʌn]	[θʌm]	[sʌn]
Coronalization & Stopping	[tʌn]	[θʌm]	[sʌn]